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MEMORANDUM REPORT NO. 2774

NUCLEAR THERMAL EFFECTS ON THE OUTER MATERIAL OF THE BLAST HARDENED S-280 ELECTRICAL SHELTER WALL

Ennis F. Quigley

July 1977

USA ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
USA BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER
BRL Memorandum Report No. 2774

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
NUCLEAR THERMAL EFFECTS ON THE OUTER MATERIAL OF THE BLAST HARDENED S-280 ELECTRICAL SHELTER WALL.

5. TYPE OF REPORT & PERIOD COVERED
Final rept.,

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Ennis F./Quigley

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
USA Ballistic Research Laboratory
Aberdeen Proving Ground, MD 21005

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
1W162118AH75

11. CONTROLLING OFFICE NAME AND ADDRESS
US Army Materiel Development and Readiness Command
5001 Eisenhower Avenue
Alexandria, VA 22314

12. REPORT DATE
JULY 1977

13. NUMBER OF PAGES
15

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
13p.

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
BRL-MR-2774

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Nuclear Thermal Effects
S-280 Electrical Shelter

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Because of the thermal insulating nature of the Kevlar-49 fiber epoxy resin composite material used in the blast hardened S-280 electrical shelter with the blast hardened wall and roof construction of the shelter, the shelter will survive the recommended nuclear thermal radiation levels. However, since the thermal environment precedes the blast environment and the Kevlar material is an integral part of the walls and roof, the blast hardness of the shelter is dependent on the effects of the thermal

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environment on the exposed Kevlar material.

Samples of the Kevlar material were exposed to several simulated nuclear thermal radiation environments. The analysis of the effects of these environments on the material show that the following effects will occur at the recommended thermal hardening level of the shelter: a) transient flaming of the exposed surface for the duration of the environment, b) the exposed layer of the multi-layered material will char and break and debond from the adjacent layer, and c) the maximum increase of the back surface temperature will be less than 108°C.

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I. INTRODUCTION

The existing S-280 electrical shelter is not hardened to the recommended nuclear blast environment levels. In order to blast-harden the shelter, its walls and roof required strengthening which was accomplished by adding a combination of a 0.23 cm thick, layered, Kevlar-49 fiber epoxy material and an aluminum honeycomb to both sides of the wall and roof panels. The resulting construction is shown in Figure 1. In addition to the blast environment, one or more sides of the shelter may be exposed to a nuclear thermal radiation environment. This environment is shown in Figure 2 where t_m (the rise time of the environment) is 0.21 s, H_m (the maximum irradiance of the environment) is 5.93 MWm^{-2}, and Q is 2.66 MJm^{-2}.

Because of the thermal insulating nature of the Kevlar material and of the blast hardened wall construction, the shelter will survive the nuclear thermal environment. However, since the thermal environment precedes the blast environment and the Kevlar material is an integral part of the wall, the blast hardness of the shelter is dependent upon the effects of the thermal environment on the Kevlar material. These effects must be determined experimentally because of the lack of the thermophysical property data for the material.

A series of tests were conducted at the White Sands Missile Range solar furnace to determine these effects and this report presents the results obtained.

II. EXPERIMENTAL PROCEDURE

Ideally, the shape and irradiance of a simulated nuclear thermal pulse should be identical to the expected real nuclear thermal pulse. Although the solar furnace has nuclear pulse shaping capabilities for weapon yields greater than 10 kt (t_m>0.115), the maximum irradiance of these pulses is 3.34 MWm^{-2} or less, the actual value being a function of atmospheric conditions. Since it was not possible to completely simulate the thermal environment, it was decided to simulate only Q using several different pulses. This decision was based on the assumption that the effects of the ideal pulse could be extrapolated from the effects obtained for the selected pulses. Three pulses were used, two square wave (SW1 and SW2) and one nuclear shape (NS). These are shown in Figure 3 along with the ideally simulated thermal pulse (INP).

Two painted samples of the material were exposed to each of the pulses. The irradiance history of each pulse was measured immediately before and after duplicated sample run using a commercial heat flux calorimeter. The average pulse parameters for each type of pulse are presented in Table I.

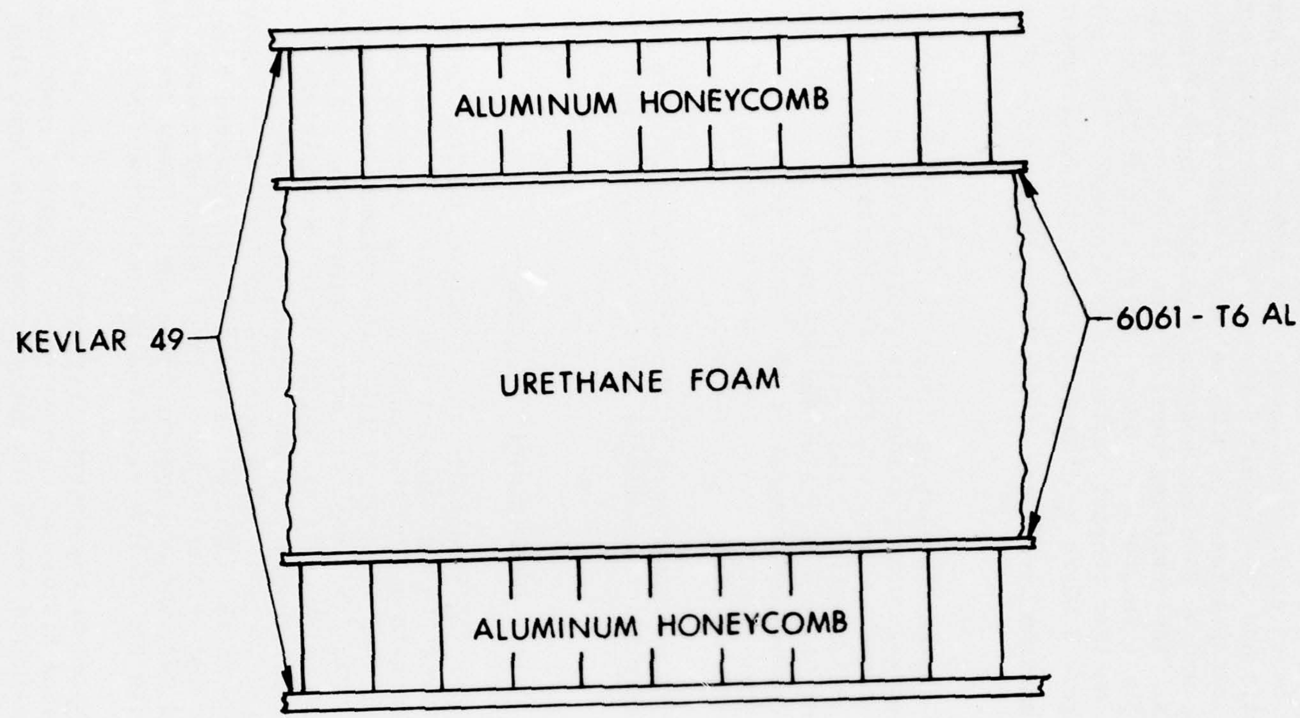

Figure 1. Blast Hardened Wall Construction

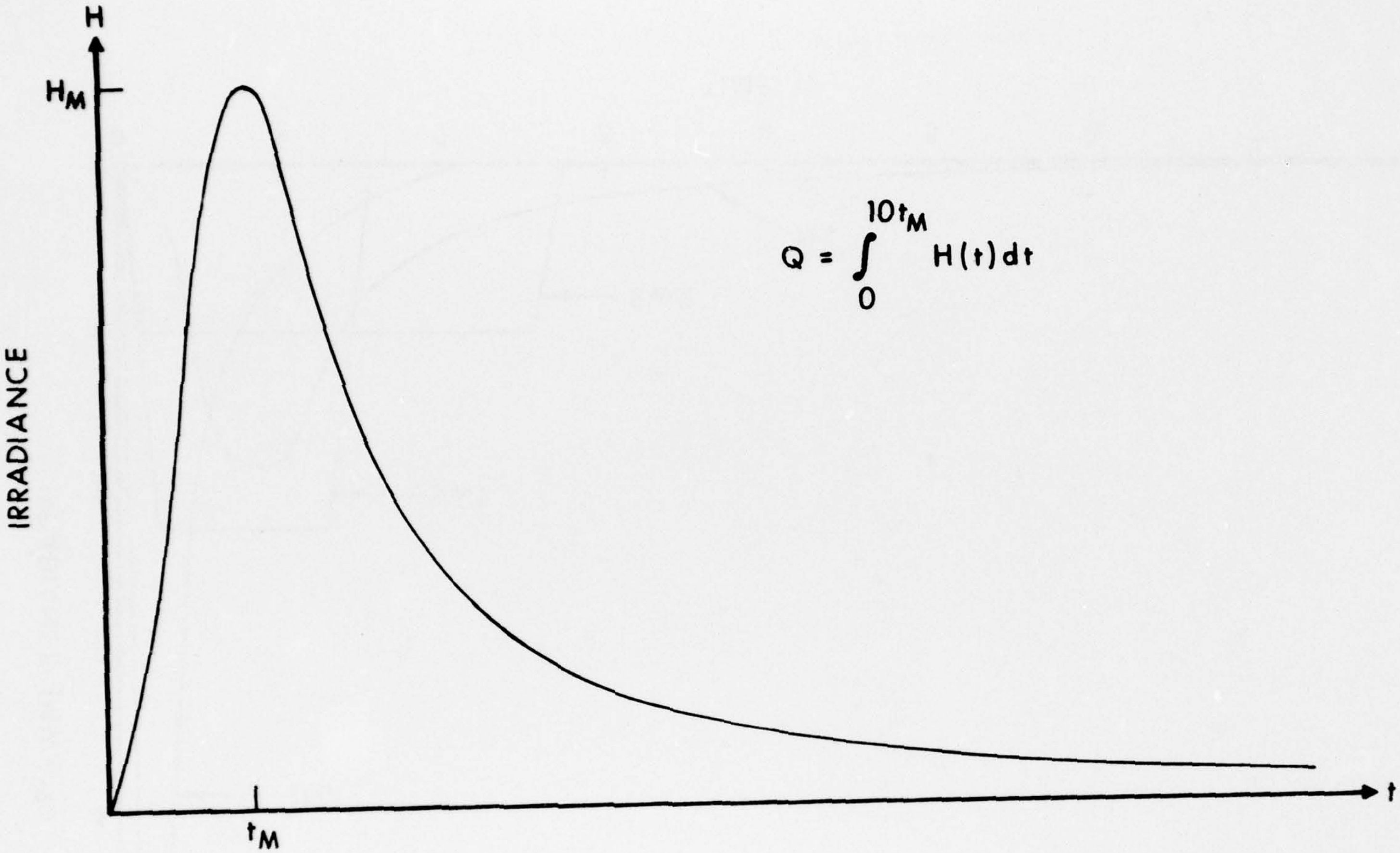

Figure 2. Nuclear Thermal Environment

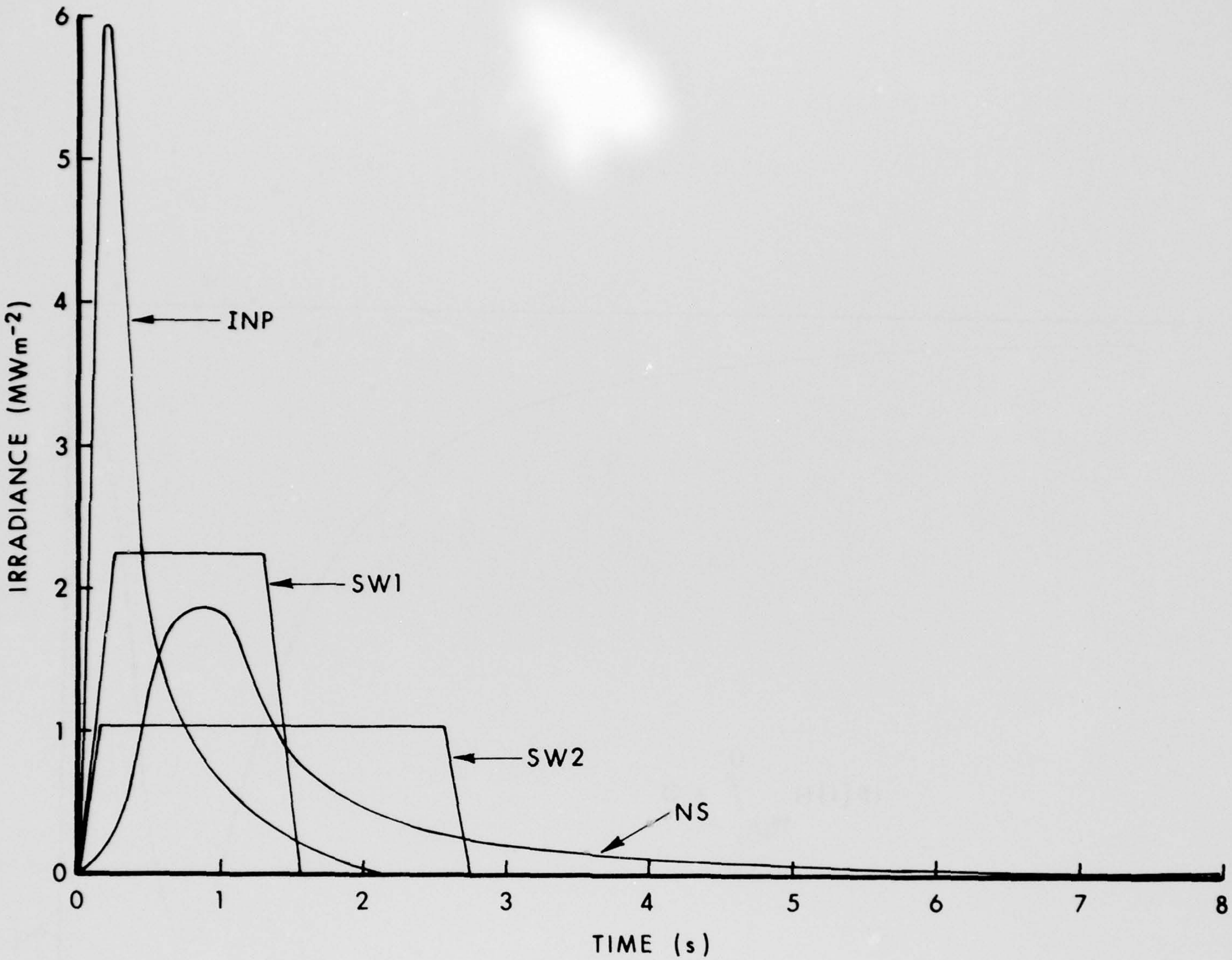

Figure 5. Experimental Thermal Environments

Table I. Pulse Parameters

Pulse	Rise Time (s)	Decay Time (s)	Duration (s)	Maximum Irradiance (MWm^{-2})	Q (MJm^{-2})
SWI	0.25	0.25	1.55	2.24	2.93
SW2	0.15	0.15	2.64	1.02	2.70
NS	0.90	7.40	8.30	1.88	2.70

The back surface temperature of each sample was monitored using Tempilabels. These are temperature sensitive materials which turn black at a specific temperature. The Tempilabels used were sensitive to 14°C increments, and the temperature data obtained was of the form $T_o<T<T_o+14°C$. High speed motion pictures of the exposed surface were taken during each sample exposure.

III. RESULTS AND DISCUSSION

Figures 4, 5, and 6 show the effects of each pulse type on the exposed surface of the Kevlar material. The effects were identical for every pulse; namely, the top layer of fibers was charred and broken, and was debonded from the next layer. Consequently, one can conclude that these effects are independent of the shape and the maximum irradiance of these pulses and that similar effects would occur from the ideally simulated environment.

A summary of the maximum, back surface temperature increase is presented in Table II where T is the temperature increase.

Table II. Maximum Back Surface Temperature Increase

Pulse	Temperature
SW1	76°C < T < 90°C
SW2	94°C < T < 108°C
NS	108°C < T < 122°C

An analysis of these temperature increases indicate that they are independent of the rise time, the maximum irradiance, and Q of each pulse. They could, however, be a function of $\int_0^t H(t)dt$. Figure 7

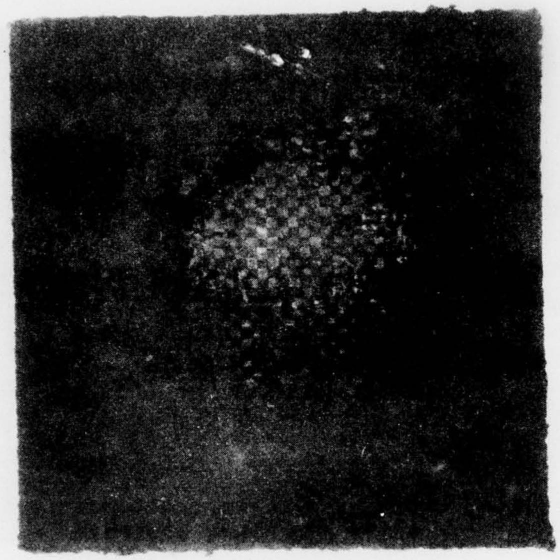

Figure 4. SW1 Pulse Surface Effects

Figure 5. SW2 Pulse Surface Effects

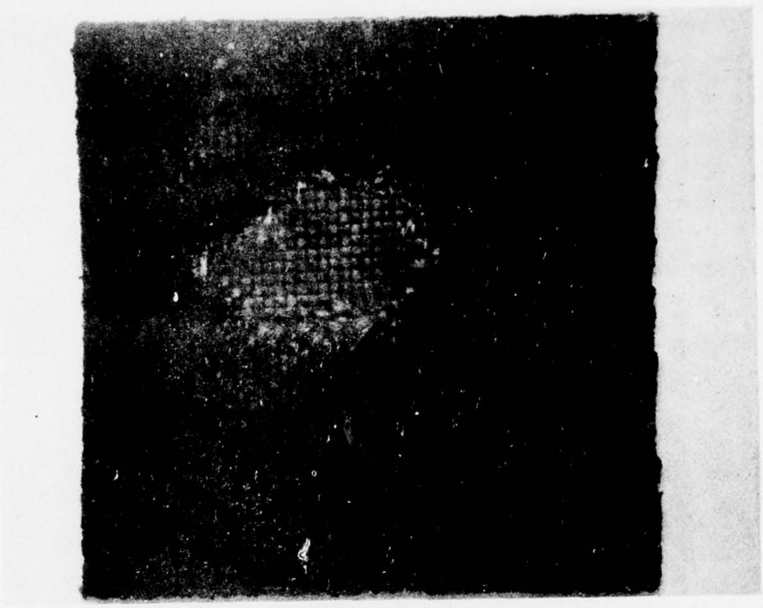

Figure 6. NS Pulse Surface Effects

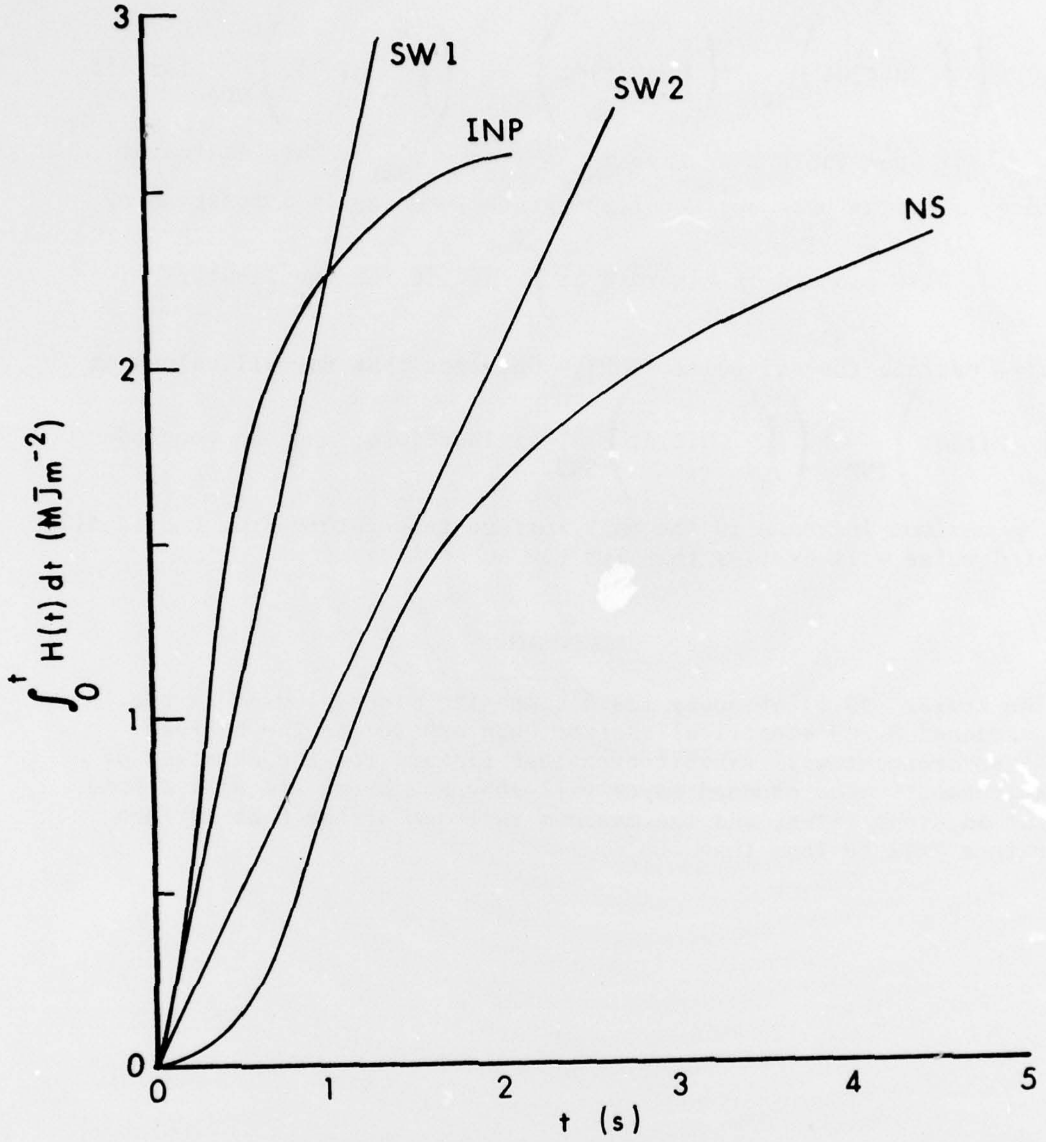

Figure 7. Total Energy Incident on Surface

shows a plot of $\int_o^t H(t)dt$ for each pulse. It is seen from this Figure that $\left(\int_o^t H(t)dt\right)_{SW1} > \left(\int_o^t H(t)dt\right)_{SW2} > \left(\int_o^t H(t)dt\right)_{NP}$ for all values of t. From Table 2 we have $T_{NP} > T_{SW2} > T_{SW1}$. This indicates therefore, that the back surface temperature increase is a function of $\int_o^t H(t)dt$. Also plotted in Figure 7 is $\int_o^t H(t)dt$ for the ideally simulated nuclear thermal pulse (INP). One sees that for all values of t, $\left(\int_o^t H(t)dt\right)_{INP} > \left(\int_o^t H(t)dt\right)_{SW2}$. Therefore, one can conclude that the maximum increase in the back surface temperature from the ideally simulated pulse will be less than 108°C.

IV. CONCLUSION

The Kevlar -49 fiber epoxy resin composite material used in the blast hardened S-280 electrical shelter when exposed to the nuclear thermal environment will exhibit transient flaming for the duration of the environment. The exposed layer will char and break and will debond from the adjacent layer, and the maximum increase of the back surface temperature will be less than 108°C.

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